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Most comfortable listening levels of hearing impaired people: effects of everyday auditory and visual environments

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"Most Comfortable Listening Levels of Hearing Impaired People: Effects of Everyday Auditory and Visual Environments"

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GENERAL LITERATURE REVIEW

Measurement of "most comfortable listening level" (MCL) has become an important clinical procedure:

1. in choosing the intensity level used during tests of unaided speech discrimination (ie. over earphones or loudspea ker)
2. in hearing aid evaluations
   a) to functionally equate hearing aids (Carhart,1946)
   b) to set the volme control of the aid during tests of aided thresholds, aided SRT, and aided discrimination in quiet and in noise (Gengel, Pascoe,& Shore, 1971; Carhart, 1946; Redell & Calvert, 1966)
3. in planning rehabilitation for the hearing impaired
   a) to determine the amount of gain needed (Victoreen, 1960; Markle & Zaner,1966; Shapiro,1976; Erber& Witt, 1977)
   b) in order to prescribe the appropriate frequency response of an aid (Gengel,Pascoe &Shore,1971; Victoreen,1973; Pascoe,1978)
   c) to determine the need for compression amplification.

This clinical judgement plays a vital role in many aspects of the audiological evaluation. Therefore, it is important to examine its reliability and validity.

A number of variables have been studied to determine their effects on a client's judgement of most comfortable listening level(s).

Investigators have shown that an ascending approach mode produces significantly lower MCL's (15-20dB lower) than does a descending approach mode (Woods,Ventry,&Gatling,1973).

Loftiss (1964) and Kopra & Blosser (1968) studied the effects of employing different psychological methods in obtaining MCL judgements. Their results indicate that this is an insignificant variable.

Increasing vs. decreasing attenuation rate in Bekesy audiometers has been shown to have a "small but significant effect" on MCL's (1-2.5dB higher when attenuation rate is increased) but to have no effect on the test-retest reliability (Ventry,Woods,Rubin,&Hill,1971). The use of an electromagnetic clutch, which enables the listener to maintain the stimulus at a constant level, did not increase the stability of the measure,as expected (Ventry, et al.,1971).

Studies comparing MCL's for continuous vs. interrupted signals have found that the MCL for a continuous signal is tracked at a lower sound pressure level than the MCL for an interrupted signal (Ventry, et al.,1971; Rintelmann & Carhart,1964).

For inexperienced listeners with normal hearing, MCL's for speech, noise, and pure tones were found to be 49.3dB SPL, 49.4dB SPL, and 51,7dB SPL, respectively. Expressed in sensation level, noise was tracked at the lowest sensation level, pure tones at the highest, and speech MCL's fell in the middle (Ventry, et al.,1971).

Johnson,Dancer, & Ventry(1977) have shown the above relationship to be different in subjects with sensorineural hearing losses. According to these authors, a wide band stimulus such as speech (spondaic words) appeared softer than interrupted pure tones of equal SPL and therefore was judged to be most comfortable to listen to at a higher SPL (10dB higher than a pure tone stimulus).

Between subject variability has been found to be high, with pure tone MCL's showing the greatest amount of intersubject

Variability and speech MCL's showing the least (Ventry, et al., 1971). The exact amounts of variability were not stated.

Within-subject reliability has been estimated to be from ±5dB (Johnson, 1977; Walden, Schuchman, & Sedge, 1977) to ± 10dB (Ventry, et al., 1971).

The effects of speaker differences and type(s) of speech material remain unquantified.

Investigators do not agree on the importance of the instuctional set. Hochberg(1974) instructed normal listeners to choose separate MCLs for intelligibility and loudness. His results showed MCLs which were 5dB greater for intelligibility than for loudness. In addition, the MCL range (upper limit-lower limit) for intelligibility was 7dB wider than for loudness. Other studies indicate that there is no significant change in MCLs for speech when subjects are instructed to use a loudness vs. a loudness-plus-intelligibility criterion. (Ventry, et al., 1971). In an unpublised study, Ventry(1977) reported that MCLs remained the same whether speech was played forward or backward. He suggests that speech MCLs "are determined, in part, by the loudness of the speech signal rather than its intelligibility.

Two studies have looked at % discrimination (intelligibility) vs. the level of presentation as it related to the listener's MCL. A study by Ullrich & Grimm(1976) showed that for normal listeners, presenting speech at MCL yielded maximum word-identification scores. However, for the majority of subjects with sensorineural hearing losses, the MCL presentation level did not produce maximum performance. Yantis, Millin, & Shapiro(1966) reported that the gain at the preferred volume setting of the listener's aid (presumably adjusted to MCL) ranged from 19dB below to 6dB above the gain at the PB max. setting.

INTRODUCTION

Whether for research or clinical purposes, judgements of MCL are typically obtained in a quiet, optically controlled environment. In everyday speech perception, however, the client usually must attempt to perceive speech in a less favorable acoustic signal-to-noise ratio, but, at the same time, has the advantage of attending to concurrent lipreading cues.

In certain situations, the listener may have some contol over these variables. For example, he may be able to position both himself and the talker, thereby improving his ability to lipread. Erber(1971,1974) showed that viewing angle, amount of illumination, and distance from the talker all have an effect on the visual speech perception performance of profoundly deaf children.

Similarly, the listener may have some control over the signal-to-noise ratio. He may be able to decrease the distance between himself and the talker, ask the talker to speak louder, or use a detachable microphone which can be held near the talker's mouth (Miller & Niemoeller,1967). Many studies have examined the effects of signal-to-noise ratio on speech perception by normal and by hearing-impaired listeners. (Hirsh,Reynolds & Joesph,1956; Speaks,Karmen, & Benitez,1967; Miller & Niemoeller,1967; Tillman,Carhart & Olsen,1970; Nabalek & Pickett,1974; Erber,1971; Gengel,1971; Elliott,1977).

A clear interaction between the availability of lipreading cues, the signal-to-noise ratio, and speech perception performance has been demonstrated. Sumby & Pollack(1954) showed that with normal-hearing subjects, speech intelligability decreases as the signal-to-noise ratio decreases when listening alone; but that this effect is reduced when the speech stimulus is presented audio-visually. At a poor signal-to-noise ratio (-30dB) there can be as much as a 40-80% difference between auditory and audiovisual scores (depending on size of response set). Ewertson & Nielson(1971) showed a change from 0-50% intelligibilty under auditory alone vs. audiovisual conditions with a signal-to-noise ratio of -20dB. Erber (1972) has studied the interaction between visual and acoustical variables as they effect normal, severely, and profoundly deaf subjects. He found that the more severe the hearing impairment the greater the signal-to-noise ratio must be to show improvement in audiovisual scores.

As one author stated, "There is a need to concentrate on the interplay between audition and vision in order to elaborate clinically applicable methods which will indicate a realistic impression of the communicative powers of an individual with defective hearing." (Ewertson & Nielsen,1971).

Investigators have suggested that speech perception tests (Elliott,1977) and hearing aid fittings (Tillman,Carhart, & Olsen. 1970; Erber, 1972; Niemeyer,1976; Miller & Niemoeller,1967) would be more sensitive to the communicative handicap if administered in the presence of masking noise and with vs. without visual cues.

Despite the interest in the effects of noise and lipreading cues on speech perception, no one has systematically explored the effects of these two variables on preferred listening levels. Only two studies have considered MCLs in noise.

Pollack(1952) and Richards(1976) compared MCLs for pure tones and speech in quiet and in noise.

Both investigators found that as the level of background noise is increased,

1. the listener's MCL increases
2. within-subject variability decreases (particularly for speech)
3. the MCL range for each subject decreases
4. the slope of the MCL-masking level function increases

However in both of these studies, the subjects were normal-hearing listeners, the masker was white noise, the signal-to-noise ratio was listener controlled, and lipreading cues were not available. None of these represent a typical listening condition and so the results are diffucult to generalize to a real-life situation.

In everyday communication, the hearing aid user must select a comfort level setting by amplifying or attenuating both the signal <u>and</u> the noise together (in addition, he may attempt to increase the signal-to-noise ratio, as previously mentioned). Therefore, the acoustic level at which he attempts to comprehend speech optimally may change as a function of the signal-to-noise ratio in the environment and the availability of lipreading cues.

The present sutdy attempted to evaluate the changes that may occur in most comfortable listening levels when hearing aid users encounter a realistic auditory and visual environment. If such changes do occur, it would be important to consider these altered MCL's in speech discrimination testing, in hearing aid fitting, and in counseling a client.

EQUIPMENT

The acoustic and optical signals were recorded and played back on a Sony Videotape Recorder (Model AV-3600). The acoustic noise signal was recorded and played back on a Sony Cassette Tape Recorder (Model TC204SD).

The output of each recorder was fed to an auxilliary input of a Bogen Mixer/Amplifier (Model CHS-60A). Each input channel had an independent attenuator. This allowed the experimenter to set their relative intensities and thereby determine the speech-to-noise ratio. The two inputs were mixed prior to amplification. In this way, all attenuators at subsequent stages modified the intensity level of the speech and the noise simultaneously (ie. the attenuators controlled the overall intensity of the signal and <u>not</u> the speech-to-noise ratio). The mixed output of the amplifier was fed to a VU meter which was used for daily calibration. The mixed signals also were fed into the experimenter's attenuator (110dB range; 2dB steps). The output of the experimenter's attenuator was fed to the subject's attenuator (60dB range; 2dB steps). The steps of attenuation were calibrated with a Bruel & Kjær Sound Level Meter (Type 1613). All were found to be extremely accurate over their entire range.

The subject's control knob was labelled with arrows indicating which turning direction would make the signal louder or softer. The dial was covered, and thus the subjects had no other indication of the amount of attenuation they had chosen.

The electrical output of the subject's attenuator was fed to an impedence matching transformer and then delivered to the subject monaurally, via TD-H49 earphones in MX-41/AR cushions.

The system's signal-to-noise ratio (with no noise input) was found to be greater than +50dB. The maximum output (with 0dB attenuation) was 135.5dB SPL. The electrical speech waveform was visualized on an oscilliscope, and soft peak clipping was found to occur at 0 and +2dB of attenuation. Neither of these two settings had to be used in bracketing any of the subject's most comfortable listening levels.

The optical speech signal appeared on a 19" black-and-white video monitor which was directly in front of the subject at a distance of approximately 2 meters. During those conditions in which the audio signal was presented alone, the screen was covered.

All audio signals were measured in octave bands using a Bruel & Kjaer Sound Level Meter (Type 1613), the TD-H49 earphones used in the study and a standard 6cc. coupler; with the attenuators set to deliver an overall level of 84dB SPL (C scale) See Figure 1.

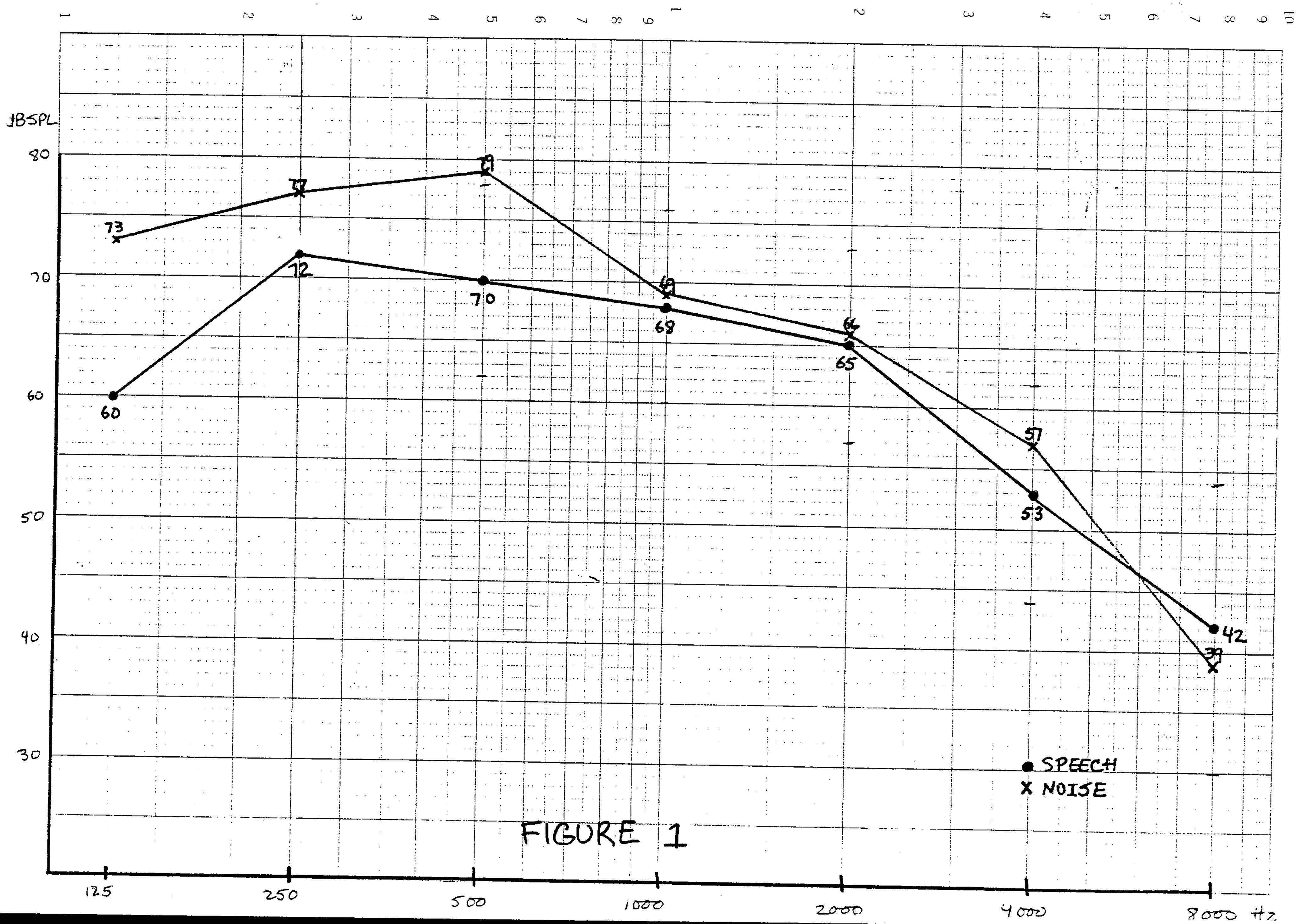

dBSPL
80
70
60
50
40
30
73
77
79
69
66
57
39
60
72
70
68
65
53
42
● SPEECH
X NOISE
125
250
500
1000
2000
4000
8000 Hz

FIGURE 1

MATERIALS

The speech stimuli consisted of 25 brief (approximately one minute) stories taken from a Specific Skills Series, entitled "Locating the Answer - Booklet A" (Richard A.Boning, Barnell Loft, LTD.,1965). The material was chosen so that it would be of at least some interest to adult listeners and yet not above the language levels of the deaf children who also participated in this study.

The noise signal was a recording of a 20-talker babble. This type of noise was chosen because:

1. it is the type of background noise that hearing aid users typically report as the most disconcerting
2. peak-to-peak vs. RMS measurements were calibrated and found to approxiamte those in everyday speech ie.(peak-to-peak) - (RMS) values were:

500	1k	2k	4k	8k
8dB	8dB	7dB	9dB	12dB

3. both peripheral and perceptual masking effects are likely to occur (Carhart, et al.,1974)
4. it is the kind of background noise often used in testing speech discrimination in noise and in many hearing aid evaluations
5. the spectrum of the noise was found to be similar to other types of typical background noise (Niemeyer, 1976)

SUBJECTS

Three groups of subjects participated in this study.

The first group contained four severely to profoundly deaf children ranging in age from 9 to 13 years; with mean hearing-threshold levels for the better ear between 80 and 100 dBHL (ANSI,1969); and with speech detection thresholds between 70 and 100dBSPL. All were congenitally hearing impaired, had been using amplification for most of their lives, and were attending a special oral school for the deaf.

The second group contained four moderate to severely hearing impaired adults ranging in age from 27 to 57 years; with mean hearing-threshold levels for the better ear between 40 and 80 dBHL (ANSI,1969); and with speech reception thresholds (for spondee words) between 35 and 75dBHL. Their experience with amplification ranged from 3 to 20 years and all were presently or previously enrolled in lipreading classes.

All subjects in these two groups were considered "successful" hearing aid users.

The third group contained three normally-hearing college students between the ages of 23 and 25. All had at least two years of experience lipreading deaf children.

PROCEDURES

Each subject participated in four experimental sessions of approximately 30 minutes each. The ear the subject used for amplification was used as the test ear. For those subjects wearing binaural aids, the left ear was chosen as the test ear.

During each session, the subjects made four determinations of the "unaided" most comfortable listening level under each of four experimental conditions:

1. auditory reception alone; in quiet
2. audiovisual reception; in quiet
3. auditory reception alone; in noise (0dB speech-to-noise ratio)
4. audiovisual reception; in noise (0dB speech-to-noise ratio)

The order of presentation of conditions was randomized over the four sessions.

At the beginning of each session, the subjects read a set of instuctions explaining how the attenuator could be used to control the stimulus intensity. The instructions were a modified version of theose used by Ventry, et al. (1971) for tracking speech MCLs; simplified so that the language level was appropriate for all aubjects. (See Appendix A). In addition to the written instructions, the experimenter verbally described the bracketing technique; encouraging the subjects to take their time, and to explore levels above and below their initial estimate of MCL.

At the beginning of each trial, the experimenter set her attenuator and recorded attenuation (in dB). The starting position on the subject's attenuator was always 60dB. These techniques effectively minimized subject bias regarding position of his control knob.

The appropriate speech (audio, visual) and noise stimuli were turned on, and the subject bracketed his MCL. He indicated that he had made a judgement by pushing a button on the attenuator box. This turned on a light which alerted the experimenter to turn off the stimuli and read the attenuation setting (in dB) from a digital display. The subject's attenuator was reset to 60dB, and the experimenter's attenuator was reset to a new value.

All determinations of MCL, for each condition, were averaged to arrive at four separate mean MCL values for each subject.

RESULTS

The average time required for a subject to make one judgement of MCL was approximately one minute.

All of the data points for each subject are shown in Figures 2-4; for the hearing-impaired children, hearing-impaired adults, and normal listeners, respectively.

Each subject's mean MCL and variability about the mean was plotted as a function of listening condition. Figures 5-7 show the results obtained for each of the three groups. The standard deviation obtained for each listening condition was plotted for each subject (see figures 8-10).

Results indicate that the hearing-impaired children showed almost no change in mean MCL as a function of the listening condition (less than or equal to 2.5dB change between any two conditions, for any subject). For 3 out of 4 subjects, the intrasubject variability was largest when listening in noise. Subjects #1 and #2 showed the greatest variability in the "auditory alone,in noise" condition. Subject #4 showed the greatest variability in the "audiovisual in noise" condition. Subject #3's large variability in the "auditory alone,in quiet" condition can be attributed to one divergent data point (see fig.2). If this point were eliminated subject #3 would show the greatest variability when listening in noise, as do the other subjects.

The hearing impaired adults did tend to show a change in the mean MCL as a function of listening condition. A consistent pattern, however, did not occur for the group as a whole. Subject #1 showed a +17.57dB change in mean MCL between the

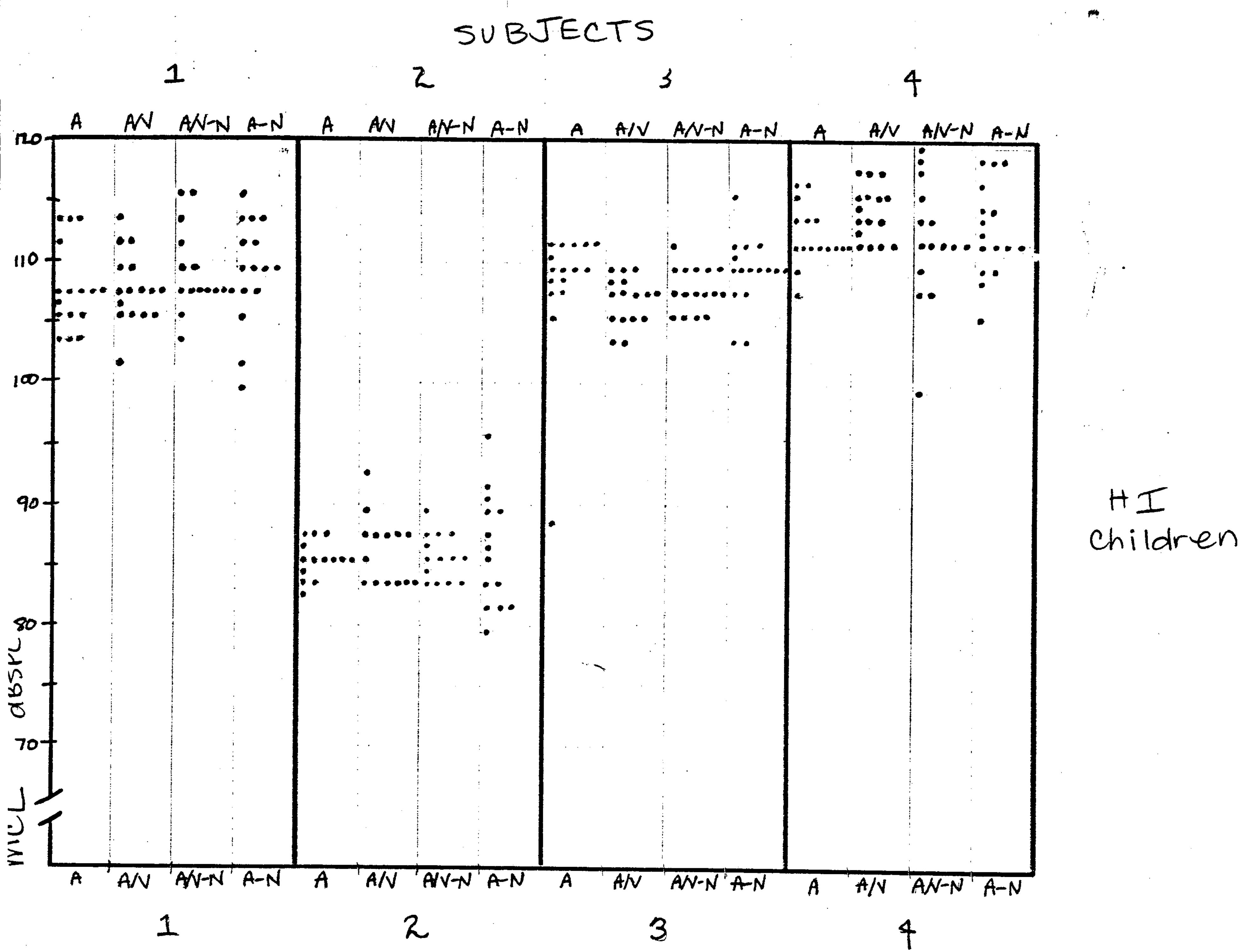

SUBJECTS
1
2
3
4
A
A/V
A/V-N
A-N
120
110
100
90
80
70
MCL dBSPL
HI
Children

FIG. 2

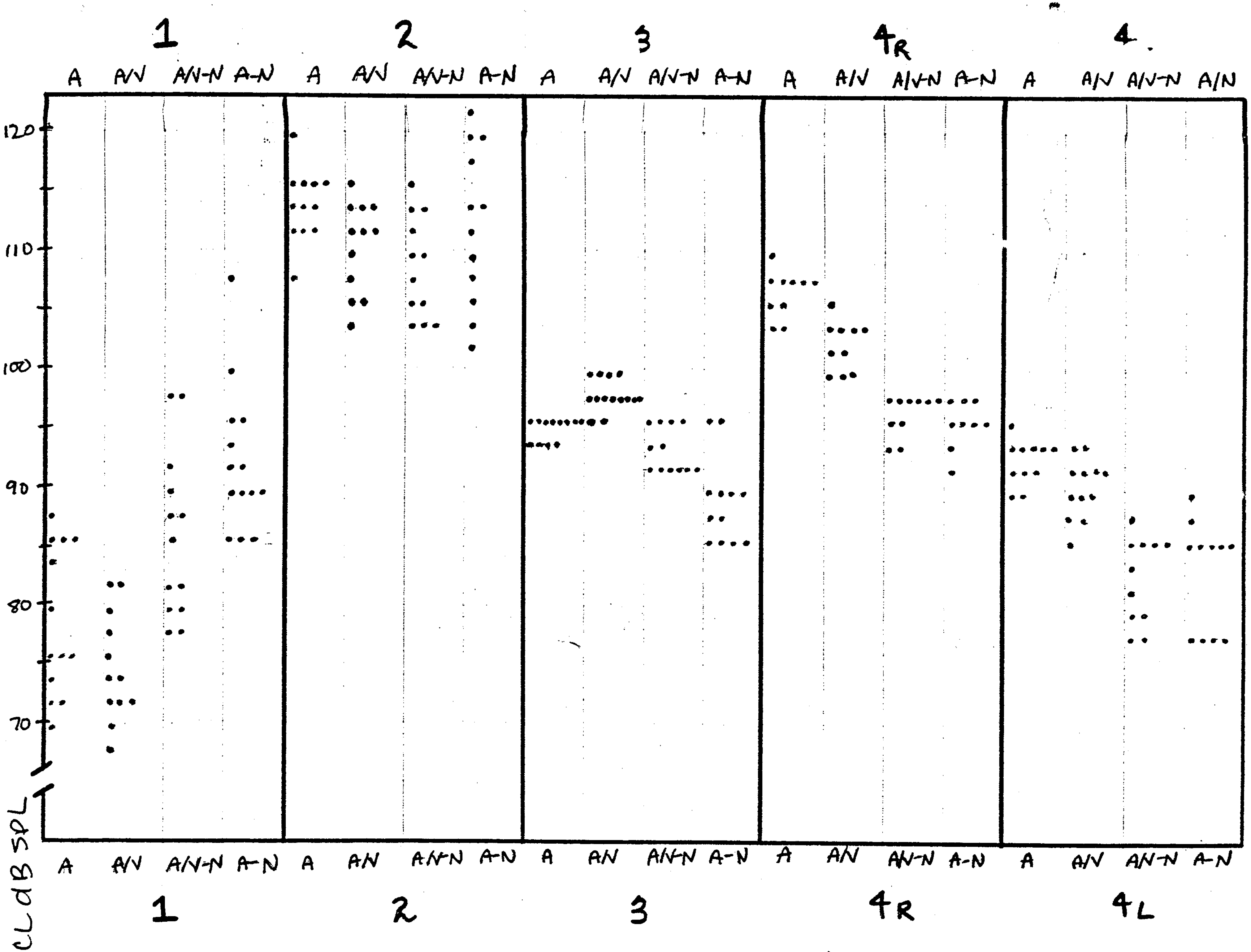


FIG. 3 HI Adults

"most favorable"(audiovisual in quiet) and "least favorable" (auditory alone in noise) condition (see fig.6). Subject #2 showed a small increase (+3dB) in mean MCL as a function of eliminating lipreading cues (independent of the noise/quiet variable). Subject #3 showed a general decrease in mean MCL when listening in noise (97.29 and 94.33dB in quiet vs. 92.67 and 88.33dB in noise). There was an 8.96 dB increase in mean MCL between listening in the most favorable A/V) and in the least favorable (A in N) condition. Subject #4's right and left ears were tested. For both ears, there was a 6-11dB decrease in mean MCL when listening in noise vs. in quiet. The presence or absence of lipreading cues under each quiet/noise condition had little additional effect (less than 1.25dB) see fig.6&7.. Despite the above between-subject inconsistencies, it should be noted that in 4 out of the 5 hearing-impaired adult ears tested, judgements of MCL showed their greatest variability when listening in noise. In 3 out of the 5, there was a progressive increase in variability from condition #1-#4 (A...A/V...A/V in noise...A in noise).see fig.6.

As a group, mean MCLs for normal listeners do not show a consistent pattern of change as a function of listening condition but large differences do occur for subject#1 and#3. In all three subjects, however, there was an increase in variability when listening in noise (regardless of the availability of lipreading cues). Results also indicate a further increase in variability when listening in noise without lipreading cues vs. with lipreading cues.

10 out of the twelve ears tested showed a maximum variability when listening in noise.

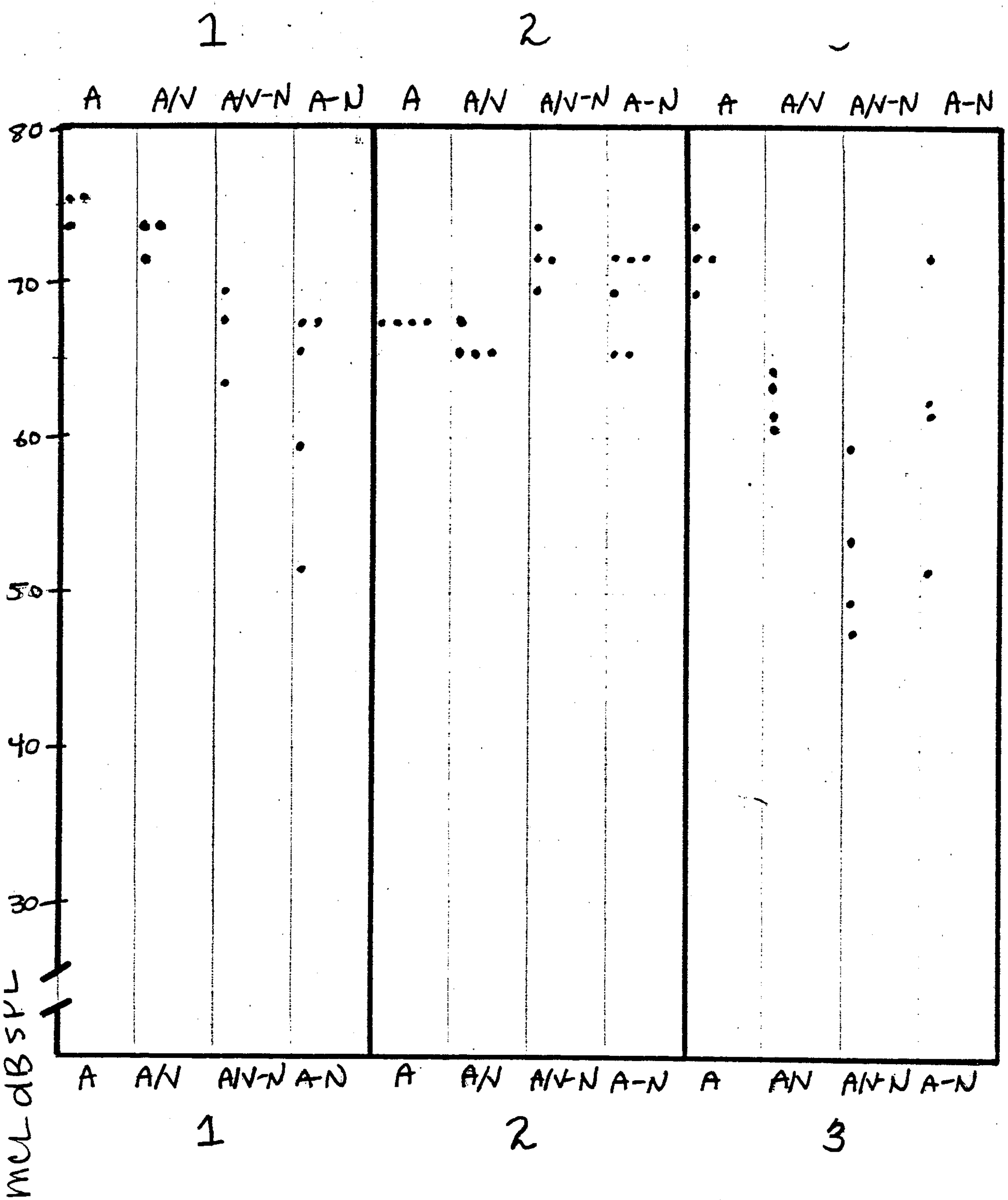


FIG. 4

NORMAL
HEARING
LISTENERS

HI Children

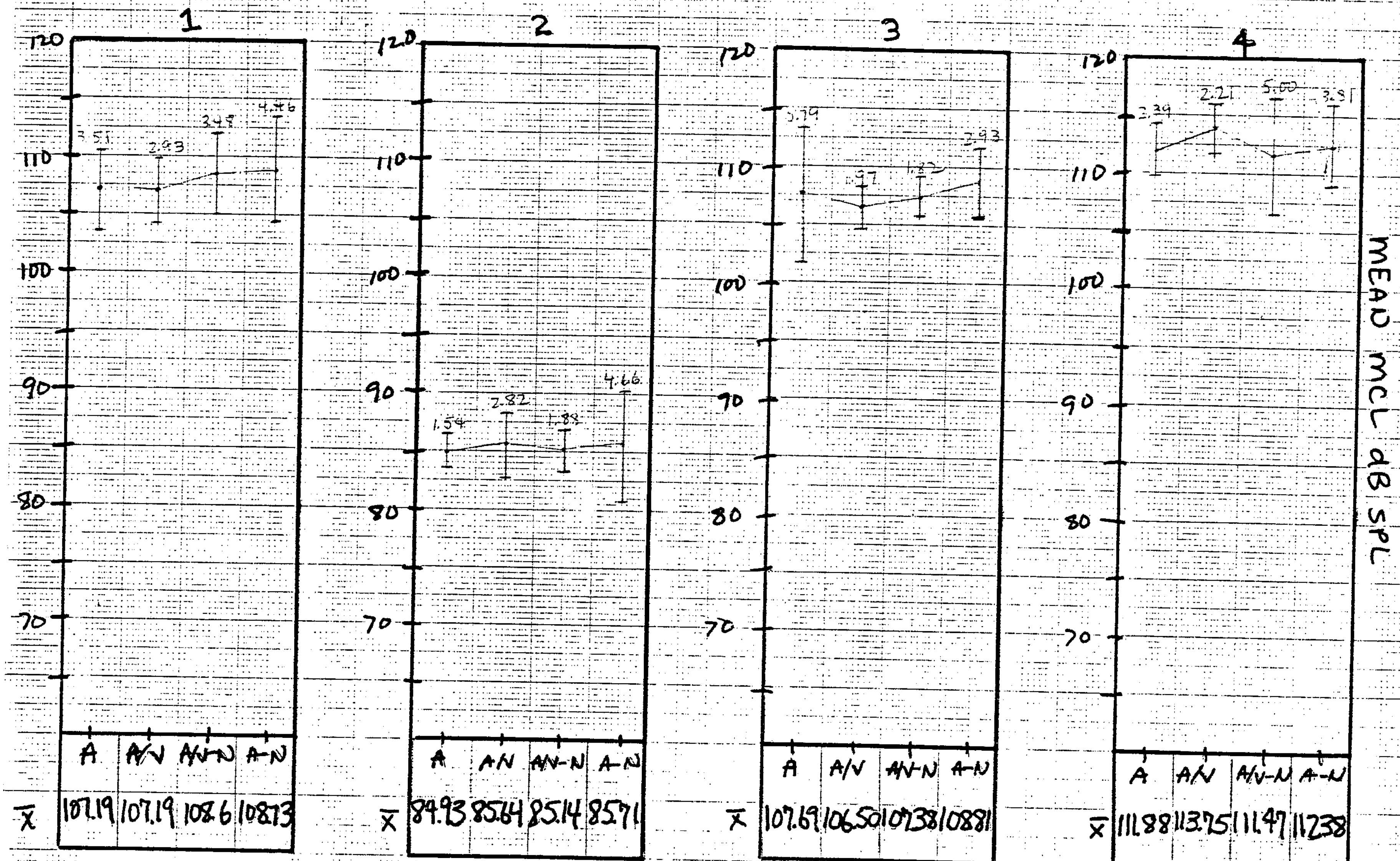
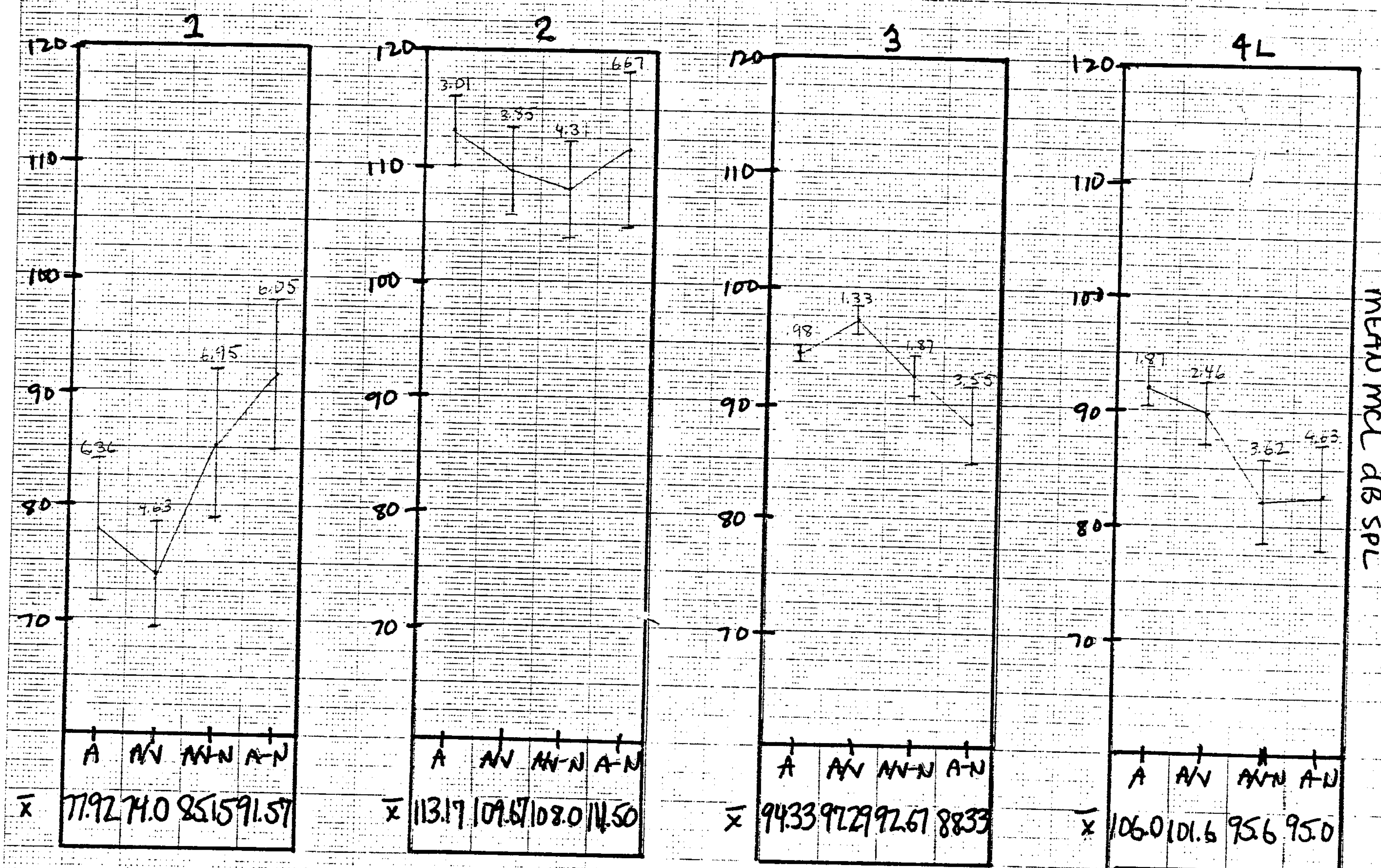


FIG. 5

HI ADULTS



	A	A/V	A/V-N	A-N
1 $\bar{x}$	77.92	74.0	85.15	91.57
2 $\bar{x}$	113.17	109.67	108.0	111.50
3 $\bar{x}$	94.33	97.29	92.67	88.33
4L $\bar{x}$	106.0	101.6	95.6	95.0

FIG. 6

NORMAL HEARING LISTENERS

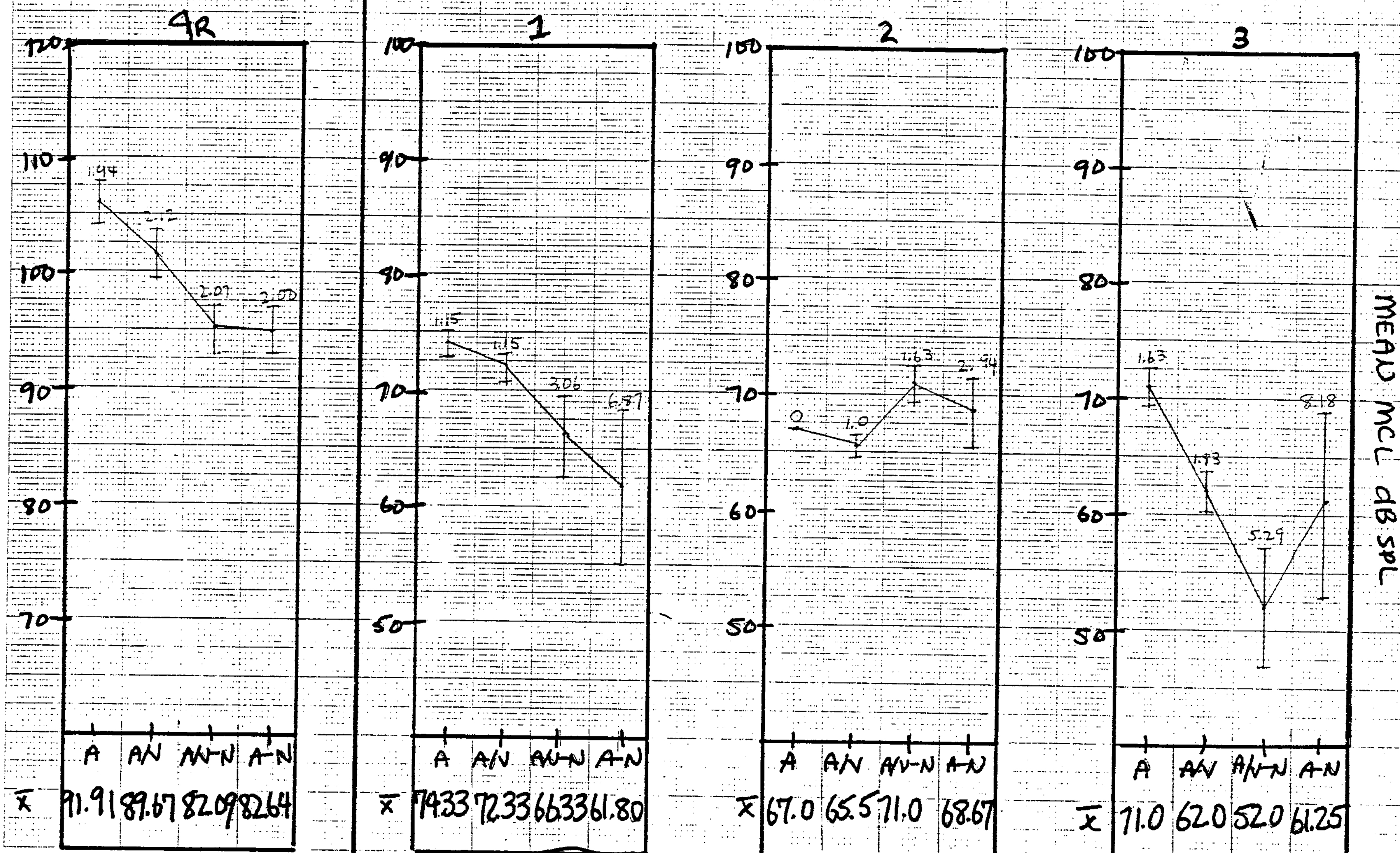


FIG. 7

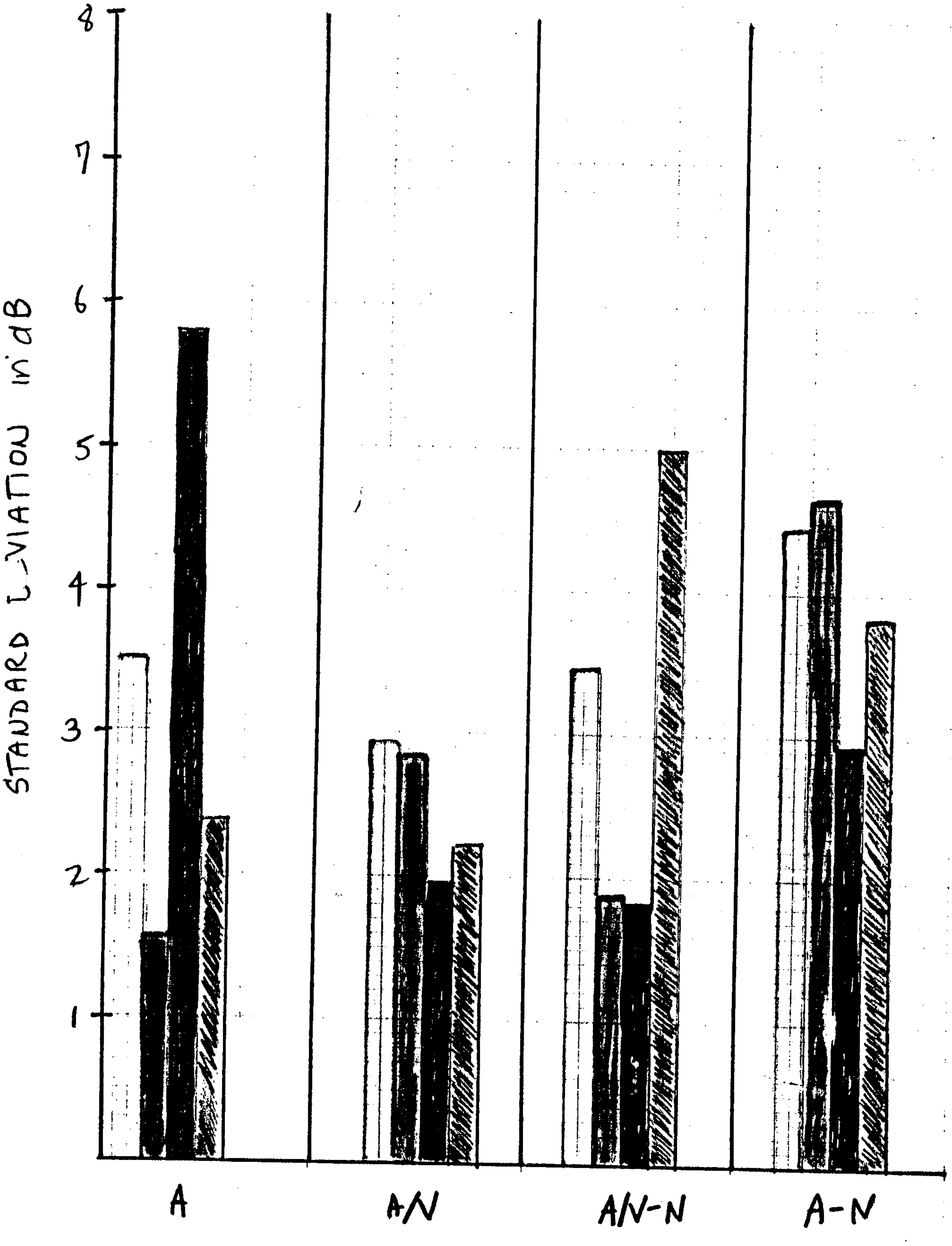


FIG. 8 H. I. CHILDREN

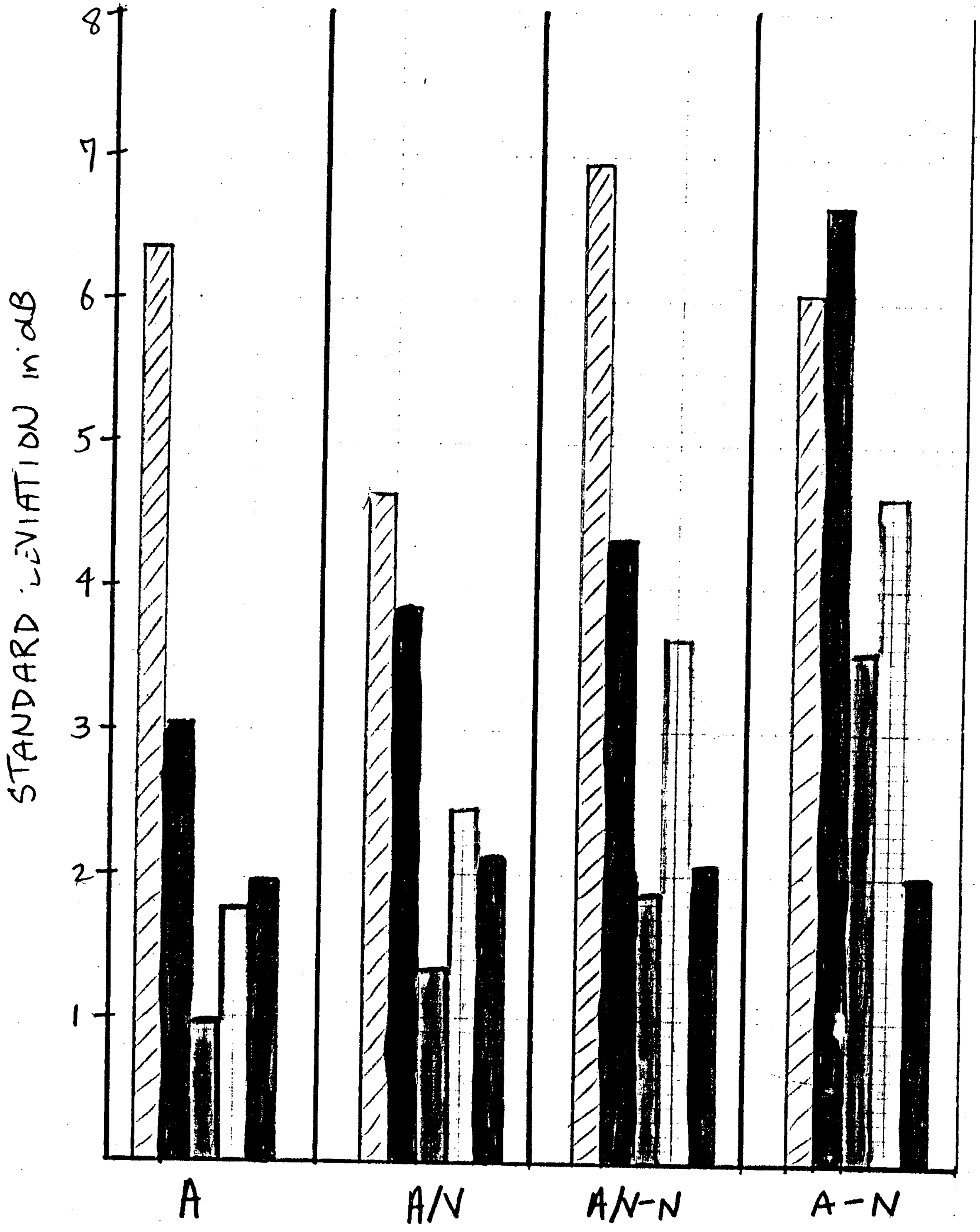


FIG. 9 H.I. ADULTS

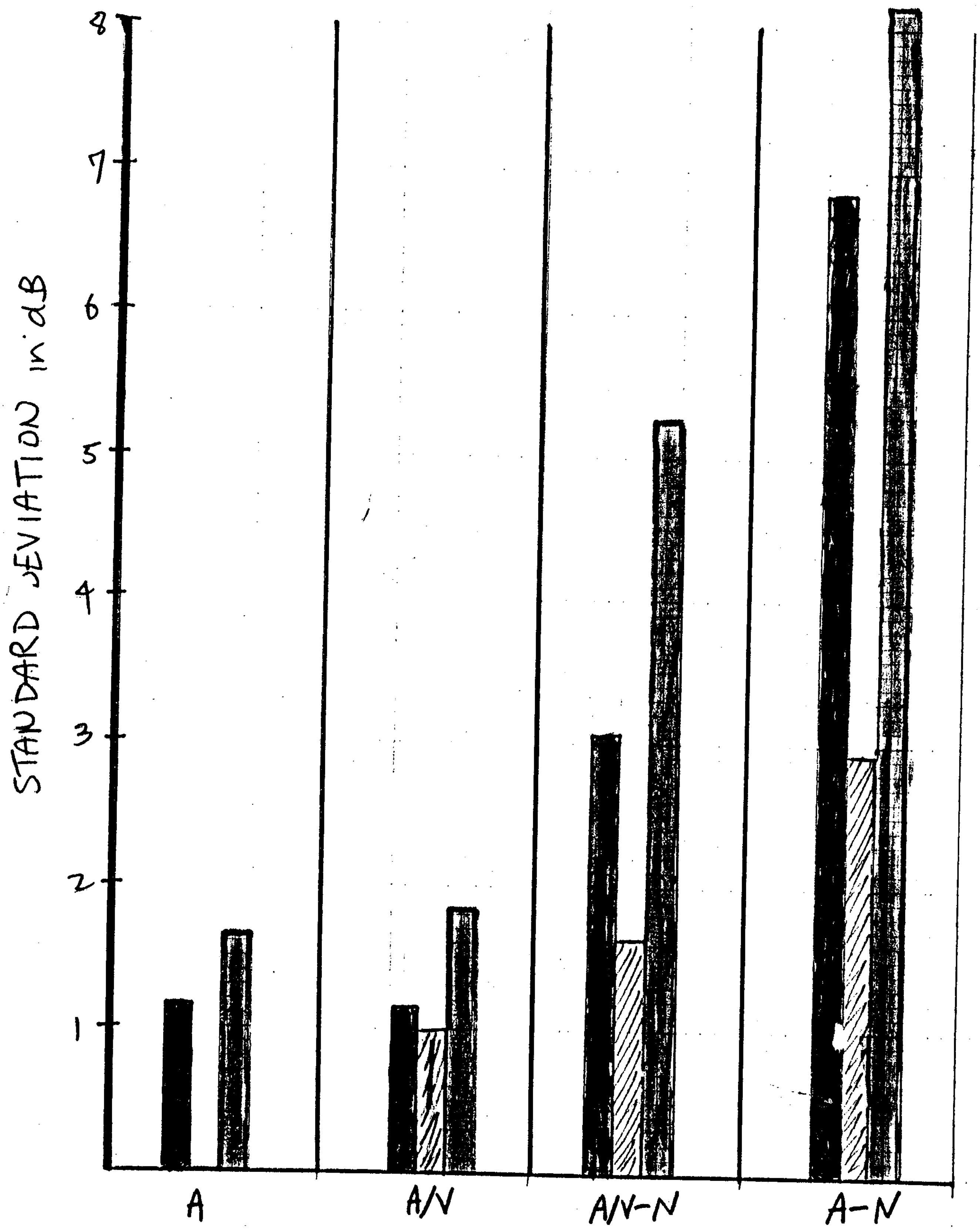


FIG. 10 NORMALS

DISCUSSION

The subjects in this study showed a variety of changes in mean MCL as a function of the listening environment. It is difficult to generalize across subjects about the effects of realistic audiovisual environments on preferred listening levels.

It seems evident, however, that all subjects did <u>not</u> show a consistent increase in MCL when listening in noise; as did the normal hearing subjects in Pollack(1952) and Richards'(1975) studies. In addition, the subjects in this study showed an <u>increase</u> in variability when listening in noise, rather than the predicted decrease (see fig.11). These two discrepancies with previous research indicate that when listeners encounter a fixed, rather than variable, speech-to-noise ratio, they may not adjust MCLs in the ways previously described in the literature.

Informal comments made by the subjects during the study revealed that when <u>listening in noise</u>, they were uncertain with regard to how to approach the task. Several of the adult listeners (normal <u>and</u> hearing impaired) were unsure whether to adjust for maximum "comfort" or maximum "intelligibility". They never raised this question during the quiet listening conditions. In addition, they seemed less "confused" by the task when lipreading cues were provided (A/V in noise vs. A in noise).

Results of previous studies (Ventry,1971; Posner,1974) indicate that in the quiet there is little, if any , difference between a listener's perceived comfort and intelligibility. Therefore, subjects should have little difficulty performing the task reliably (in quiet). A non-adjustable speech-to-noise ratio may create an environment, however, in which maximum comfort and maximum intelligibility do not occur at the same sound pressure level.

Once the listener becomes aware of the two separate components (comfort and intelligibility) that are influencing his preference judgements, he may experience doubt regarding which is the "important" feature to attend to. This uncertainty may cause him to shift from one criterion to the other, either between trials or between test days. He may adjust the sound pressure level with reference to the component that appears to change most as a function of intensity (eg. volume control rotation).

For example, a listener may experience a large change in intelligibility with a small change in intensity, but little difference in comfort. Intelligibility, in this case, would be the more salient feature.

Other listeners may be unable to understand much of the speech in a OdB speech-to-noise ratio regardless of overall intensity. Because changing amount of gain will not change the speech-to-noise ratio, these hearing aid users may find that comfort is the only component that varies as a function of volume control rotation. Consequently, these listeners might have a tendency to adjust for maximum comfort.

A discrepancy between sound pressure level for maximum comfort and sound pressure level for maximum intelligibility may have led to the increase in variability when the subjects listened in noise, as demonstrated in this study. It is possible that at more favorable speech-to-noise ratios, listeners may experience greater ease in combining the two components (eg. as in quiet environments).

8 out of the 10 subjects who showed a maximum variability in noise, had greater variability when listening in noise without lipreading cues than with lipreading cues. Sumby and Pollack (1954) demonstrated that visual cues show their greatest contribution to intelligibility at low signal-to-noise ratios. In this study, we can assume that during the "audiovisual in noise" condition, the addition of visual information improved the intelligibility of the speech signal. Therefore, when listening in noise, lipreading cues may have made it easier for the subjects to choose a single level for both maximum comfort and maximum intelligibility (analogous to improving the speech-to-noise ratio). This could explain the somewhat reduced variability seen when listening in noise with lipreading cues as compared to without lipreading cues.

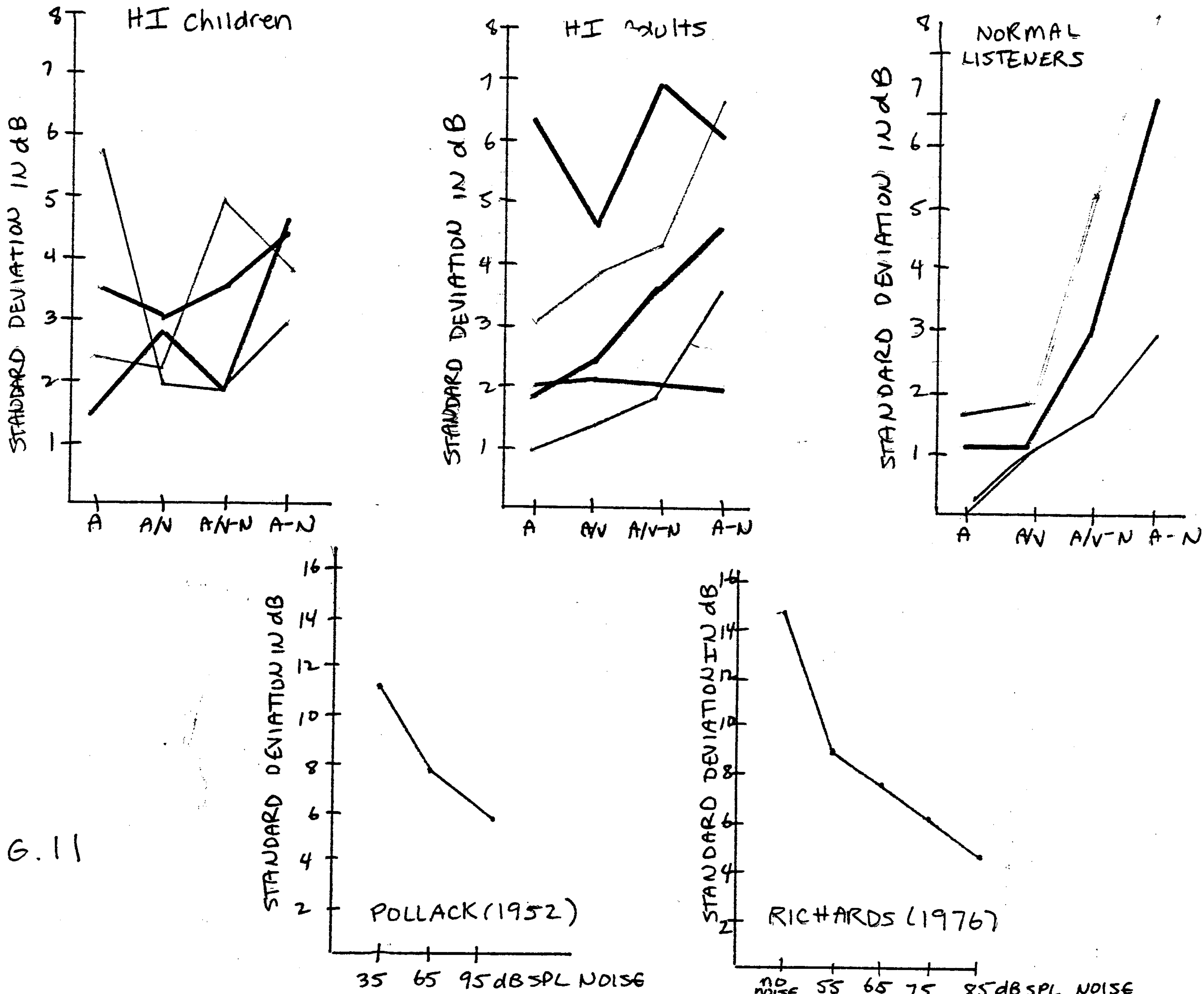
As mentioned earlier, hearing-impaired clients will use their hearing aids most often in environments in which they can not control the speech-to-noise ratio. The results of this study indicate that:

1. The assumption that naiive listeners can reliably set the volume control of their aids for maximum speech intelligibility may not be true when one tests in noise.

2. In order to accurately measure speech intelligibility in noise, the instructions should specify either a comfort <u>or</u> intelligibility criterion for setting the gain of hearing aids.

3. The probability that an individual will be a "successful hearing aid user" may depend, in part, on the disparity between these two judgements in a realistic audiovisual environment.

4. In order to appropriately counsel clients, audiologists should be able to discuss the interaction that occurs between comfort and intelligibility in real life audiovisual environments and recommend strategies for improving these two aspects of speech perception.



HI Children
STANDARD DEVIATION IN dB
8
7
6
5
4
3
2
1
A
A/N
A/V-N
A-N
HI Adults
STANDARD DEVIATION IN dB
NORMAL LISTENERS
STANDARD DEVIATION IN dB
16
14
12
10
8
6
4
2
STANDARD DEVIATION IN dB
POLLACK (1952)
35
65
95 dB SPL NOISE
STANDARD DEVIATION IN dB
RICHARDS (1976)
NO NOISE
55
65
75
85 dB SPL NOISE

FIG. 11

APPENDIX A

INSTRUCTIONS:

Listen to the woman talking. She'll be reading you a story. You will not always be able to see her. LISTEN CAREFULLY.

The dial will let you make the sound louder and softer. Turn the dial until it sounds MOST COMFORTABLE to you. Not too loud and not too soft.
You want to understand as much as you can but if it gets too noisy you can turn it down. If you can't hear the woman talking you can turn it up.

Remember, pick a level that would be the MOST COMFORTABLE to listen to for a long time.

Take your time.

Push the button when you've picked the setting that is MOST COMFORTABLE.

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